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Heavy Fertilization Increases Diameter Growth Slightly in a 55-Year-Old Ponderosa Pine Stand in Central Arizona

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In a stand of Rocky Mountain ponderosa pine thinned to a minimum spacing of 20 by 20 feet (6.10 by 6.10 m), 0, 500, and 1,000 pounds of urea ammonium phosphate (28–28–0) per acre (0, 560.19 and 1,120.38 kg/ha) were applied annually from 1974 to 1977, to six replications of four trees in randomized blocks. Although fertilization at the heavier rate significantly increased diameter growth, height growth was not affected by any of the treatments.

Keywords: *Pinus ponderosa*, fertilization, forest mensuration

Ponderosa pine (*Pinus ponderosa* var. *scopulorum* Engelm.) grows slowly in the Southwest. This often is a result of deficient precipitation, competing vegetation, soils, and overstocking. In many areas, overstocked stands, often containing 5,000 to 10,000 stems per acre (12,350 to 24,700 stems/ha), are the result of the abundant 1919 crop of regeneration.

Schubert (1974) showed dramatic increases in growth when trees in these stands were released by thinning. Periodic annual diameter increment in stands with a residual basal area of 30 square feet (2.79 m^2) is more than 0.3 inch (0.76 cm), compared to about one-third of that for a stand with a residual basal area of 120 square feet (11.15 m^2) (Schubert 1974). Fertilizing thinned stands has been considered to speed growth even further.

Wagle and Beasley (1968) found fertilization actually decreased height growth of ponderosa pine in some cases. Cochran (1971) found initial height increased in response to various levels of N, P, S, and B. Pitcher (1972) determined that fertilization did not increase the height growth of loblolly pine (*P. taeda* L.) in Illinois; Winston (1977) reported the same findings for jack pine (*P. banksiana* Lamb.) in Canada. Miller and Wert (1979) reported that neither foliar nor soil applied N had any measurable effect on height growth of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*). Other reports indicated that Douglas-fir (Steinbrenner 1968), sand pine (*P. clausa* (Chapm.) Vasey), and slash pine (*P. elliottii* var. *elliottii* Engelm.) (Brendemuehl 1968, Malac 1968) increased in height after fertilization.

This study was designed to determine the effect of different amounts of urea ammonium phosphate fertilizer (28–28–0) on flowering, seed production, and growth in an even-aged stand of ponderosa pine in the Southwest. Effects on cone and seed production were reported by Heidmann (in press).

Methods

Study Area

In 1974, a 10-acre (4.05-ha) area on the Coconino National Forest, near Flagstaff, Ariz., was chosen to study the effect of thinning and fertilization on a 55-year-old natural stand of ponderosa pine. The site is in the *Pinus ponderosa/Festuca arizonica* habitat type, *Festuca arizonica* phase (Hanks et al. 1983). The stand was thinned to a growing stock level[2] of 40 square feet per acre (9.18 m^2/ha) in 1963, and the slash was piled and burned. The soil is well developed and classified as a Mollic eutroboralf. The surface 0- to 6-inch (0 to 15.24

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[2] *Growing stock level is the residual square feet of basal area when the average stand diameter is 10 inches or greater. Average stand diameter is the diameter of the tree of average basal area; it is not the average of all the tree diameters.*

cm) depth ranges from a silt loam to a silty clay loam, while the 12- to 18-inch (30.48 to 45.72 cm) depth varies from a clay loam to a clay. The pH is between 6.0 and 7.0.

Treatments

In August 1974, the stand was further thinned to a minimum spacing of 20 feet (6.1 m) between residual trees in order to minimize effects of root competition and more fully expose the crowns. Slash was removed from the study site, and herbaceous vegetation was eliminated by scalping with a small crawler tractor. Approximately 1 to 2 inches (2.54 to 5.08 cm) of topsoil was removed accidentally from the site by scalping. Each study tree was pruned to a height of 10 feet (3.05 m) before treatments were applied.

Six blocks of three plots each were established in the thinned stand. Each plot contained four pole-sized trees. Overall initial mean diameter at breast height was 9.6 inches (24.38 cm), and mean height was 31.6 feet (9.63 m).

Each study plot within a block was randomly assigned one of the following annual fertilizer treatments:

1. Control—no fertilizer treatment.
2. 500 pounds per acre (560.19 kg/ha) urea ammonium phosphate fertilizer, providing 140 pounds (63.50 kg) of N and 140 pounds (63.50 kg) of P_2O_5 per acre (156.85 kg of each/ha).
3. 1,000 pounds per acre (1,120.38 kg/ha) urea ammonium phosphate fertilizer, providing 280 pounds (127.01 kg) of N and 280 pounds (127.01 kg) P_2O_5 per acre (313.71 kg of each/ha).

Each tree was considered to be the center of a circular plot with a diameter equivalent to two-thirds of the total tree height. Thus, the area fertilized, at these rates, varied with the size of the sample trees. Fertilizer was applied each year on top of snow in late fall or early December, 1974 to 1977.

Measurements

Before treatment in 1974, and each succeeding fall, diameter at breast height and total height of each tree were measured to the nearest 0.1 inch (0.25 cm) and 0.5 foot (15.24 cm), respectively. An analysis of variance was used to assess pretreatment differences for height and diameter between assigned treatments. There were no significant differences (table 1).

A standard U.S. Weather Bureau rain gage has been maintained on the site since 1976. The gage is charged with oil and antifreeze and is weighed every month, except when the area is inaccessible because of snow. Precipitation data prior to 1976 is from the Fort Valley Experimental Station headquarters, approximately 4 miles (6.44 km) distant. Total yearly precipitation at both areas is similar.

Annual growth was calculated by subtracting initial values from final values and dividing by number of years. Differences in height and diameter growth data were determined by analysis of variance with repeated measures.

Results and Discussion

There were no significant differences in height growth among the trees during the study period (table 1). Height growth during the period of fertilization (1974–77), however, was significantly greater than for the period after fertilization (1977–81) for all treatments. The reason for this decreasing rate of height growth is not known. It does not appear to be related to precipitation, which was generally higher after fertilizer treatments ceased (table 2).

Diameter growth is greater for the 1,000 pounds per acre (1,120.38 kg/ha) fertilizer rate than the control ($P = 0.06$), but not different from the 500 pounds per acre (560.19 kg/ha) rate. After fertilization, diameter growth for all treatments is similar to growth during the period of fertilization. This may indicate a carryover effect of fertilizer or may be a result of increased precipitation (table 2).

Table 1.—Diameter, height, periodic annual increment, and standard deviation for ponderosa pine at Wild Bill seed production area in Arizona.

	Fertilizer treatment		
	Control	500 lb/acre	1,000 lb/acre
Diameter at breast height		*inches*	
1974	9.29 a[1]	9.75 a	9.78 a
1982	12.05	12.79	13.09
Periodic annual increment	0.34 a[2]	0.38 ab	0.41 b
Standard deviation	.0427	.0494	.0411
Total height		*feet*	
1974	31.00 a[1]	31.58 a	30.79 a
1981	38.33	38.95	37.46
Periodic annual increment	1.05 a[2]	1.05 a	0.95 a
Standard deviation	0.1368	0.1554	.0432

[1]*Means with the same letter in common are not statistically different at the 0.05 level as determined by analysis of variance. Comparisons are between treatments.*

[2]*Means with the same letter in common are not statistically different at the 0.06 level as determined by analysis of variance. Comparisons are between treatments.*

Table 2.—Monthly precipitation (in inches) at Wild Bill experimental seed production area, 1974–81.

	1974	1975	1976	1977	1978	1979	1980	1981	$\bar{X}$
Jan.	2.84[a]	0.98	0.17	0.72	3.37	3.30	5.84	0.96	2.27
Feb.	5.00	1.98	3.91	0.69	3.78	1.79	6.43	0.90[a]	3.06
Mar.	0.77	2.39	1.59	1.03	5.67	2.61	2.96	3.26	2.54
April	0.54	1.69	2.30	1.00	1.27	0.41	2.17	0.89	1.28
May	0.05	0.89	2.37	1.68	0.31	2.51	1.82	1.20	1.35
June	T	0	0	1.58	0	0.07	0.48	0.34	0.31
July	2.14	5.39	3.13	2.17	2.34	0.79	1.48	0.45	2.24
Aug.	1.74	1.21	0.48	2.75	1.34	2.51	1.17	9.08	2.54
Sept.	0.93	1.23	1.72	1.34	0.55	0.03	0.10	3.02	1.12
Oct.	2.85	0.26	0.48	1.65	1.37	1.41	0.96	1.62	1.32
Nov.	0.73	2.00	0.03	1.10	5.53	1.10	0	1.75	1.53
Dec.	0.63	0.94	1.68	1.41	3.13	1.03	0.89	0.38	1.26
Total	18.22	18.96	17.86	17.12	28.66	17.56	24.30	23.85	20.82

[a]*Data to the left of the solid line are from Fort Valley Experimental Forest, as well as February 1981.*

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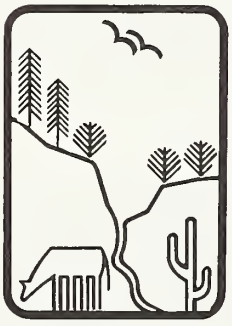
Rocky Mountains



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